Patent Application of

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For

TITLE: ENGINE TIMING CONTROL WITH INTAKE AIR PRESSURE SENSOR

CROSS REFERENCE TO RELATED APPLICATIONS Not Applicable

FEDERALLY SPONSORED RESEARCH Not Applicable

SEQUENCE LISTING Not Applicable

BACKGROUND OF THE INVENTION -- FIELD OF INVENTION

The present invention is directed to an intake air pressure sensor assembly for an internal combustion engine, and in particular, a fuel-injected engine that communicates with a controller for controlling the fuel injectors and ignition timing based on detected air pressure fluctuations.

BACKGROUND OF THE INVENTION

In all fields of engine design there is emphasis on fuel economy, engine performance, and most notably, engine-out emissions. Increased emissions restrictions have led to the necessity of a more accurate fuel metering process. Fuel injection systems have emerged as an accurate way to control the air and fuel mixture in an internal combustion engine and thus keep emissions low. The trend towards fuel injection has not been without added costs, and as such has limited the applications of this technology in price sensitive markets. To apply fuel injection to an engine, one must add an engine controller, a more complex fuel system,

and multiple sensors. In addition, engines often need to be redesigned to allow for the application of these control electronics. All of these components add costs and complexity to the engine system. Many manufacturers simply cannot be competitive with the added costs of fuel injection in their product line, and as such are delaying its implementation until emissions regulations mandate its use. It would be ideal to have an accurate system for controlling an internal combustion engine that is less complex and less costly to implement on current engine technology.

A four-stroke engine must rotate two complete rotations for one full engine cycle. This cycle is comprised of the intake, compression, power, and exhaust strokes. The four-stroke cycle is based on a 720° cycle, or two complete rotations of the crankshaft. In relation to four-stroke engines, the engine phase determines which half of the 720° cycle the engine is on. For example, if a four-stroke engine is "in phase" on a 720° cycle, it is considered synchronous, and the engine controller can correctly determine which stroke the engine is on. If the four-stroke engine is not synchronous, the engine controller can only determine engine position on a 360° cycle. Many systems must determine engine phase to obtain the appropriate timing on four-stroke engines. A two-stroke engine must only rotate one complete rotation for a complete engine cycle. No phase information must be obtained from this engine cycle. This will be referred to as a 360° engine cycle.

Typically, a fuel injection system utilizes a plurality of sensors on the engine to determine engine operating conditions. For example, a fuel-injected engine may be equipped with a crankshaft position sensor, cam position sensor, intake air pressure sensor, and barometric air pressure sensor in addition to other sensors. The engine controller monitors these sensory inputs to determine the appropriate ignition timing, injection timing, and quantity of fuel to be injected. It would be beneficial to reduce the number of sensors necessary to operate an engine, yet maintain accurate control. This would result in fewer components, less complexity, and reduced costs.

One of the various types of data monitored by these sensory inputs to the engine controller is the determination of the intake air pressure. This measurement process can be quite complex. This challenge can be complicated further by monitoring intake air pressure in engines with few cylinders. It is well known in the art that intake pressures fluctuate with the opening and closing of the intake valves during the intake stroke. If there is a plurality of cylinders there will be more intake events per crankshaft rotation and traditionally less overall intake air pressure fluctuations. However, if few cylinders are present as in small engines, there will be fewer intake events per crankshaft rotation and large intake air pressure

fluctuations will be apparent. If the average intake pressure were to be obtained, it will not be an accurate indication of actual cylinder intake air pressures due to these fluctuations.

Air pressure sensors have been used in the calculation of intake air mass seen by reference to US Pat. Number 6,453,897 to Kanno. In this approach, the intake air pressure of the engine is sampled just once per engine crankshaft revolution. It is generally understood in the art that the air pressure can be used for intake air mass calculations in fuel injection control. Kanno presents a system that has increased accuracy for measuring intake air pressure and therefore increased accuracy in obtaining intake air flow rate and desired air/fuel ratio in the engine. This example presents no applications to determining engine phase or crankshaft position through the air pressure fluctuations. Instead, this approach strictly pertains to a single air pressure measurement at a predetermined crankshaft position. The timing of this measurement is determined through the use of a crankshaft position sensor and engine control unit.

In some applications, the mass air flow rate into the engine is estimated in part by measuring the absolute pressure within the induction manifold (Manifold Absolute Pressure, or "MAP"). A mass air flow rate is the mass of air drawn into an engine over a particular period of time. Air density, or mass per unit volume, is proportional to air temperature, pressure, and humidity of the air drawn into the engine. This data is used to calculate the mass air flow rate of the engine, or mass of the incoming air. Such calculations are known as volume-density or speed density calculations.

With crankshaft position measurement, a toothed wheel is typically used in conjunction with a pickup to detect positional movement. These devices are traditionally hall effect devices or variable reluctance devices. In automotive applications, the toothed wheel consists of multiple teeth or "timing slugs" evenly spaced on the crankshaft. The number of teeth is traditionally a whole divisor of 360°. As the number of teeth is increased, resolution of the system is increased. In many applications, there is a missing tooth to indicate a predetermined position on the crankshaft itself. An automotive standard of today is known as a "36-1" pattern. This pattern evenly spaces 36 gear teeth on a ring, and has one of the 36 teeth removed to indicate a predetermined angular position. From this input, engine rpm and crankshaft position can be directly measured. Unfortunately, the crankshaft rotates twice for a complete 720° cycle in four stroke engines. A crankshaft position sensor can not indicate engine phase on a four-stroke engine because of this. The crankshaft will be in the exact same position twice during the engine cycle. Additional sensory information is required to synchronize to a 720° cycle, if the engine controller is to operate in a synchronous manner. If

the crankshaft is keyed to indicate its position, it is only possible to determine engine position based on 360° cycle, or a single crankshaft rotation without additional sensory information.

Many small engines utilize a crankshaft trigger mechanism for indicating a predetermined crankshaft position for ignition purposes. With this mechanism an ignition spark is emitted every 360° of crankshaft rotation. This type of system is similar to a crankshaft position sensor with the distinction of having only a single signal indicating pulse per crankshaft revolution. A system of this nature typically is not in communication with an engine control device, but is rather part of a stand-alone ignition system. As such, there is little or no memory from one cycle to the next. These systems cannot predict engine timing for fuel injection purposes due to crankshaft acceleration and deceleration. They can however consistently trigger an ignition system at a fixed crankshaft angular position.

To determine engine phase on four stroke engines, an additional sensor is typically used in conjunction with a crankshaft position sensor. A camshaft position sensor may be used to determine an engine's phase. The camshaft rotates at exactly half the speed of the crankshaft and they are mechanically linked. Therefore, these two sensory inputs provide the engine controller with engine position information to run on a synchronous basis to a 720° engine cycle. Due to its nature, a camshaft position sensor is not as accurate as a crankshaft position sensor and therefore they are typically used in combination.

In most applications, these are all discrete and separate sensors. Each sensor traditionally has only a single role in monitoring engine conditions. They each require their own wiring, connectors, and tooling to be mounted to the engine. These multiple parts all add in the cost of fuel injection implementation. Additionally, if the crankshaft position sensor were to fail for any reason, little or no redundancy is implemented and the engine would cease to operate.

It would be advantageous to reduce the number of sensors necessary to run the engine. If this could be done, cost savings would be realized in fewer sensors, reduced tooling, reduced fixturing, reduced assembly time, and lower design costs. If fewer sensors were required to accurately control fuel injection timing, it would enable a more cost efficient transition of non-fuel injected engines to the technology.

BACKGROUND OF INVENTION-OBJECTS AND ADVANTAGES

Accordingly, several objects and advantages of my invention are the multiple uses of a single intake pressure sensor to control the timing of an internal combustion engine. This invention was designed for use on a single cylinder engine, but may be applicable to, but

without limitation to, all forms of internal combustion engines exhibiting intake pressure fluctuations. This invention reduces the number of sensors necessary to determine engine timing and operating characteristics by monitoring intake pressure fluctuations.

To effectively time an engine, this invention can replace the crankshaft position sensor, cam position sensor, manifold air pressure sensor, and barometric pressure sensor with a single part. With this technology a single intake air pressure sensor could be used as a stand-alone engine timing mechanism. By monitoring the intake pressure fluctuations, one would obtain a vacuum pulse every two crankshaft rotations (in a four stroke engine). This is indicative of a particular crankshaft position and the time when the intake valve is open. When implemented with a microprocessor, the time interval between intake pressure events could be mathematically modeled to predict when the next event would occur. In addition, this model could offer a prediction of crankshaft position sub-cyclic to the intake pressure events. With this timing information, fuel metering and ignition timing could accurately and precisely be added to an engine in a non-intrusive form. No additional sensors need to be hard tooled or machined into the engine block material. This may be of specific benefit to companies that want to add fuel injection technology to an existing product. This system, while not having resolution as high as a "36-1" tooth crank position pick-up on an automobile engine, offers excellent accuracy at much lower costs.

Many small engines of today use some form of crankshaft trigger for their ignition system. If a crankshaft trigger or crankshaft position sensor input were combined with the technology of this patent, increased accuracy and resolution would be obtained in engine timing. Using a crankshaft trigger alone does not allow an engine to be timed on a 720° cycle (in four stroke applications). With the input of the intake pressure fluctuations in addition to a crankshaft trigger, and engine may be aligned in phase on a 720° cycle. When implemented with a microprocessor, the system can be mathematically modeled to predict and monitor intake pressure events. With this information, a much higher resolution can be obtained than in the previous example. With this timing information, fuel metering and ignition timing could accurately and precisely be added to an engine in a non-invasive form.

Redundancy is obtained in a system of this nature. If one of the two sensors were to fail, the other sensor would provide ample signal to enable the engine to continue to be operated, with reduced resolution. This may be a valuable benefit if the engine were to be placed into a vehicle where engine failure cannot be tolerated in the field.

Due to the location of the pressure sensor in the intake tract, this allows for engine manufacturing to be simplified. Tooling, engineering, and design time does not have to be

invested in placement of multiple sensors in the engine castings. This control system specifically benefits manufacturers who may want to add fuel injection to an existing carbureted product. The non-invasive nature of this invention lends itself to applications in engines where tooling, packaging, or redesign costs are too high to consider standard fuel injection applications.

Further objects and advantages of my invention will become apparent from a consideration of the drawings and ensuing description.

SUMMARY OF THE INVENTION

A need therefore exists for a less complex fuel injection control system for cost sensitive applications. This invention presents a novel approach for a low cost, low complexity engine timing control for fuel injection applications.

One aspect of the present invention is a method to reduce the complexity of the fuel injection system through using an intake air pressure sensor to determine engine position and phase. Pressure fluctuations are present on the intake stroke of the engine and are mechanically related to the opening and closing of the intake valve. The movement of the intake valve is mechanically linked to the crankshaft angle and hence the timing of the engine. There is an intake event every two crankshaft rotations in four-stroke applications, and once every crankshaft rotation for two-stroke engines. The presence of these pressure fluctuations is therefore indicative of engine phase (in four stroke applications), crankshaft position, engine speed, and can directly measure engine rpm. With this information, crankshaft position can be quantitatively measured and engine timing can be determined.

This invention can be used as a stand alone engine timing mechanism, or in addition to a crankshaft trigger/position sensor to accurately time an engine. This system offers less resolution than automotive "36-1" tooth crankshaft position sensors, yet offers excellent position sensing and engine timing at a much lower cost and complexity. The inherent non-invasive nature of this technology lends itself to be easily added to almost any pre-existing internal combustion engine configuration.

Thus, a manufacturer of engines would find it very easy to add the technology of fuel injection to their current product line. They would not need to hard tool or support multiple new sensors in their engine line. This invention allows for relative ease in the addition of fuel injection to engines not currently designed for the technology. The present invention allows

for a low cost and extremely robust implementation of fuel injection on an internal combustion engine.

DRAWINGS--FIGURES

FIG. 1 is a schematic view showing a single cylinder internal combustion engine, configured in accordance with the preferred embodiments of the invention. The intake tract and part of the engine are shown generally in the upper portion of the figure. The engine controller is shown in the lower left portion of the figure. The Engine Controller, sensors, and fuel injection system link the two views together.

FIG. 2 is a schematic illustration of an air induction system of the engine shown in FIG. 1, with the pressure sensor mounted thereon.

FIG. 3 is a graphical illustration of the timing relationship between an output signal of the pressure sensor shown in FIG. 2 and actual crankshaft position.

DRAWINGS--REFERENCE NUMERALS

10 Internal combustion engine
12 Power head
14 Air induction system
15 Fuel injection system
16 Exhaust system
20 Cylinder block
22 Cylinder bore
24 Piston
25 Crank case
26 Cylinder head
30 Crankshaft
32 Connecting rod
34 Combustion chamber
40 Intake port
44 Intake valve
46 Exhaust valve
60 Throttle plate
62 Throttle position sensor
63 Intake air temperature sensor
64 Intake air pressure sensor
65 Crankshaft position sensor
66 Throttle plate axis of rotation
67 Fuel injector
68 Throttle shaft
69 Ignition system
70 Ignition signal
72 Injector signal
74 Intake pressure signal
76 Throttle position signal
78 Intake air temperature signal
79 Crankshaft position signal
80 Engine Control Unit (ECU)
86 Exhaust port
88 Exhaust pipe

90 Intake plenum
92 Plenum chamber
94 Intake runner
96 Induction air passage
98 Throttle body
100 Opening of the intake valve
101 Exhaust stroke
102 Intake stroke
103 Compression stroke
104 Power stroke
110 Closing of the intake valve
112 Approximate barometric pressure
115 Engine cycle
120 Intake air pressure signal
125 Opening of the intake valve
130 Closing of intake valve
140 Angular Crankshaft Position
145 360° of Crankshaft Rotation
148 End of 720° Engine Cycle
150 0° of Crankshaft rotation

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

FIG. **1** shows an internal combustion engine **10** for use in an All Terrain Vehicle (ATV, or Four-wheeler). The present invention may also find utility in applications using internal combustion engines, such as, for example but without limitation, personal watercraft, small jet boats, off-road vehicles, heavy construction equipment, motorcycles, lawn tractors, and gas powered yard implements.

As used throughout this description, the terms "forward", "front" and "fore" mean at or to the forward side of exhaust system **16**, and the terms "rear", "reverse" and "rearwardly" mean at or to the opposite side of the front side, unless indicated otherwise.

The engine **10** operates on a four-stroke combustion cycle. As shown in FIG. **1**, the engine **10** includes a cylinder block **20**, which defines a cylinder bore **22**. In the illustrated embodiment, the engine **10** is of the single cylinder type.

It is to be noted that the engine may be of any type (V-type, Inline, W-type), may have other numbers of cylinders, and/or may operate under other principles of operation (two-stroke, rotary, or Diesel principles).

A piston **24** reciprocates in the cylinder bore **22**. A cylinder head assembly **26** is affixed to one end of the cylinder block **20** and defines a single combustion chamber **34** with the piston **24** and cylinder bore **22**. Both ends of the cylinder block **20** are closed with a crankcase member (not shown) defining a crankcase chamber **25** therein.

The engine **10** includes and air induction system **14** and an exhaust system **16**. The air induction system **14** is configured to supply air charges to the combustion chamber **34**.

With reference to FIG. **2**, the induction system **14** includes a plenum chamber member **90**, which defines a plenum chamber **92** therein. The intake runner **94** extends from the plenum chamber **92** and defines an induction air passage **96** therein. The intake passage **96** extends from the plenum chamber **92** to the intake port **40** formed in the cylinder head assembly **26**.

With reference to FIG. **1**, the intake port **40** is opened and closed by the intake valve **44**. When the intake port **40** is opened, air from the intake passage **96** and intake port **40** flows into the combustion chamber **34**.

The plenum chamber **92** preferably includes an inlet opening that opens to the external air supply (not shown). The opening to the plenum chamber **92** preferably includes some form of air filtration device (not shown). The plenum chamber **92** functions as an intake air silencer and/or a collector of air charges. The plenum chamber **92** is positioned on the rearward side of the engine **10** and the induction passage extends frontward from the plenum chamber **92** to the intake port **40**.

As shown in FIG. **2**, a throttle body **98** is provided within the intake runner **94**. The throttle body **98** supports the throttle plate **60** for pivotal movement about an axis **66** of a throttle shaft **68**, which extends generally vertically through the respective throttle body **98**.

The throttle plate **60** is operated via a throttle cable (not shown). The throttle cable is connected to a thumb throttle (not shown) that may be provided on the handlebar (not shown) of the all terrain vehicle.

With reference to FIG. **1**, a throttle position sensor **62** is arranged atop of the throttle shaft **68**. A signal from the position sensor **62** is sensed by an engine controller ECU **80** via a throttle position data line **76** for use in controlling various aspects of the engine operation including, for example, but without limitation, fuel injection control and ignition timing, which will be described later. The signal from the throttle position sensor **62** corresponds to the engine load in one aspect, as well as the throttle opening.

The air induction passage **96** may include a bypass passage or idle air supply passage that bypasses the throttle plate **60**, although such is omitted from FIG **2**. The engine **10** may also include an idle air adjusting unit (not shown) which is controlled by the ECU **80**.

In operation, air is introduced into the powerhead **12** and passes through the inlet opening of the plenum chamber **92**. During operation of the engine **10**, an air charge amount is controlled by the throttle plate **60** to meet requirements of the engine **10**. The air charge then flows through the runner **94** into the intake port **40**.

As described above, the intake valve **44** are provided at the intake port **40**. When the intake valve **44** is opened, the air is supplied to the combustion chamber **34** as an air charge. Under idle running condition, the throttle plate **60** is generally closed. The air, therefore, enters the intake port **40** through the idle air adjusting unit (not shown) which is controlled by the ECU **80**. The idle air charge adjusted in the adjusting unit is then supplied to the combustion chamber **34** via the intake port **40**. The rpm of the engine **10** at idle is adjusted by varying the small opening in the throttle plate **60**. This is accomplished by adjusting a set screw (not shown) to limit the lower travel of the throttle plate **60** about axis **66**.

With reference to FIG. **1**, the exhaust system **16** is configured to discharge burnt gases, or exhaust gases, from the engine's **10** combustion chamber **34**. The exhaust port **90** is defined by the cylinder head assembly **26** and is opened and closed by the exhaust valve **46**. When the exhaust port **86** is opened, the combustion chamber **34** communicates with a single exhaust pipe **88**, which guides the exhaust gases downstream through the exhaust system **12**.

A single camshaft (not shown) is provided to control the opening and closing of the intake valve **44** and the exhaust valve **46**. The camshaft has cam lobes that act against valves **44, 46** at predetermined timing in relation to the crankshaft **30** to open and close the intake port **40** and exhaust port **90**. The camshaft is jounaled in the cylinder head assembly **26** and is driven by a chain (not shown) mechanically connected to the crankshaft **30**.

With reference to FIG. **1**, the engine **10** also includes a fuel injection system **15**. The fuel injection system **15** includes a fuel injector **67** which has an injection nozzle exposed to the intake port **40** so that fuel is directed toward the combustion chamber **34**. A main fuel supply is located in a fuel tank (not shown) from which fuel is supplied via fuel system (not shown). Fuel is dawn from the fuel tank through a fuel filter (not shown) by a fuel pump (not shown). The pressure of the fuel is regulated by a fuel pressure regulator (not shown) and the fuel is sent to the fuel rail (not shown) and provided to the injector **67** for injection into the combustion chamber **34**. Excess fuel that is not used by the injectors is fed through a fuel return line that is provided back to the fuel tank. The timing and duration of the fuel injection pulse is dictated by the ECU **80**, which is described below in detail.

The fuel charge from the fuel injector **67** enters the combustion chamber **34** with an air charge at the moment the intake valve **44** is opened. Since the fuel pressure is regulated by the pressure regulator, a duration during which the nozzles of the injector **67** are opened is determined by the ECU **80** to measure the amount of fuel to be injected by the fuel injector **67**. The ECU **80** through the fuel injector control line **72** thus controls the duration and the injection timing. Preferably, the fuel injector **67** has nozzles that are opened by solenoid

action, as is know in the art. Thus the fuel injector control line **72** signals the solenoids to open and close according to the timing and duration determined by the ECU **80**.

The engine **10** further includes an ignition system, generally indicated by reference to numeral **67**. A spark plug **65** is fixed to the cylinder head assembly **26** and is exposed to the combustion chamber **34**. The spark plug **65** ignites the air and fuel charge mixture in the combustion chamber **34** with timing as determined by the ECU **80**. For this purpose, the ignition system **69** preferably includes an ignition coil (not shown) interposed between the spark plug **65** and the spark plug control line **70**.

The engine **10** also preferably includes an AC generator (not shown) for generating electrical power. Additionally, the engine **10** preferably includes a battery (not shown) for storing electrical energy from the AC generator and to supply power to the ECU **80**, the engine sensors (Intake Air Temperature sensor **63**, Throttle Position Sensor **62**, Intake Air Pressure sensor **64**, Crankshaft Position sensor **65**), fuel pump, fuel injector **67**, and the ignition coil.

While not illustrated, the engine **10** also includes a recoil starter or electric starter motor to drive the crankshaft **30** for starting the engine **10**. The engine **10** is turned over at a speed where the engine can operate under its own power.

A transmission (not shown) is typically integrated to the engine crank case **25** casting in an engine of this type. Although it is not illustrated power is coupled from the crankshaft, through the transmission, and to the vehicle drive system to provide motion.

The engine **10** also preferably includes a lubrication system (not shown). This lubrication system is provided for lubricating certain portions of the engine **10**, such as, for example, but without limitation, the pivotal joints of the connecting rod **32** with the crankshaft **30** within the crank case **25** and the walls of the cylinder bore **22**.

The engine **10** also preferably includes a cooling system (not shown) for cooling the heated portions of the cylinder block **20** and the cylinder head **26**. A water jacket (not shown) is defined in the cylinder block **20**, and is in thermal communication with the cylinder bore **22**. A water pump (not shown) circulates the coolant through the engine **10** and a radiator (not shown).

As noted above, the ECU **80** controls engine operations including fuel injection from the fuel injectors **67** and ignition timing to the spark plug **65**, according to various control maps stored in the ECU **80**. In order to determine appropriate control scenarios, the ECU **80** utilizes such maps and/or indices stored within the ECU **80** in reference to data collected from various sensors.

Any type of desired control strategy can be employed for controlling the time and duration of the fuel injection from the fuel injector **67** and the timing of the firing of the spark plug **65**, however a general discussion of some engine conditions that can be sensed and some of the engine conditions that can be sensed for engine control follows. It is to be understood, however, that those skilled in the art will readily understand how various control strategies can be employed in conjunction with the components of the invention.

As shown in FIG. **1**, a crank position sensor **65** measures the crank angle and sends it to the ECU **80**, as schematically indicated. In the illustrated embodiment, the crank position sensor **65** is in the form of a crank trigger, which is configured to emit a single pulse for each revolution of the crankshaft **30**. The signal from the crank position sensor **65** is transmitted to the ECU **80** via a crank position data line **79**. Engine load can be sensed by the angle of the throttle plate **60**, and is sensed by the throttle position sensor **62** and is transmitted to the ECU **80** via the throttle position data line **76**.

An intake air temperature sensor **63** measures the temperature of the incoming air to the intake runner **94**. The signal from the intake air temperature sensor **63** is transmitted to the ECU **80** via the intake air temperature data line **78**. An intake air pressure sensor **64** is connected to the intake runner **94** between the throttle plate **60** and the intake port **40** and measures the pressure of the incoming air charge in the induction air passage **96**. The measurement of the intake air pressure sensor **64** is transmitted via the intake air pressure data line **74** to the ECU **80**.

The sensed conditions disclosed above are merely some of those conditions which may be sensed for under control and it is, of course, practicable to provide other sensors such as, for example, without limitation, an oxygen sensor, Fuel pressure sensor, fuel temperature sensor, Engine coolant temperature sensor, oil pressure sensor, barometric air pressure sensor, and cam position sensor.

The ECU **80** computes and processes the detected signal from each sensor based on a control map. The ECU **80** forwards control signals to the fuel injector **67** and spark plug **65**. Respective control lines are indicated schematically in FIG. **1**, which carry the control signals.

As noted above, the ECU **80** determines the appropriate duration of fuel injection in order to produce a charge with a desired air fuel ratio. Thus, part of the determination of fuel injection duration is based on the induction air through the induction passage **96**. The mass flow rate of the induction air charge through the induction passage is determined by the ECU

80 and a stoichiometric ratio of fuel is added by the fuel injector **67** as determined by the ECU **80** and fuel injector control line **72**.

During operation of the engine **10**, the ECU **80** samples the output signal from the intake pressure sensor **64** to determine crankshaft position **140** while the crankshaft **30** rotates from 0° of crankshaft rotation **150,** through 360° of crankshaft rotation **145**, and 720° or crankshaft rotation **148** . Both 360° of crankshaft rotation **145** and 720° of crankshaft rotation **148** are known as Top Dead Center as the Piston **24** is in the top most position of travel within the cylinder bore **22**. Monitoring the signal from the crank position sensor **65** adds resolution to the determination of the crankshaft position **140**. In reference to FIG. **3**, the intake pressure signal **120** fluctuates with the opening of the intake valve at **100** and closing of the intake valve at **110**, during the intake stroke **102** of the four-stroke engine **10**. During the intake stroke **102**, the intake valve **44** opens to allow the intake air/fuel charge to flow from the intake port **40** into the combustion chamber **34** creating pressure fluctuation **100** on the intake pressure signal **120** from the intake pressure sensor **64**. As the piston **24** travels to the bottom portion of its travel in the cylinder bore **22**, the intake valve **44** closes creating pressure fluctuation **110** on the intake pressure signal from the intake pressure signal **120** from the intake pressure sensor **64**.

In this embodiment, the intake pressure signal **100** to **110** from the intake pressure sensor **64** is observed every two full crankshaft rotations as the engine **10** is of the four-stroke type. The time difference between these pressure fluctuations is indicative of engine speed N and can be calculated by the ECU **80**. In addition, the pressure fluctuations **100** to **110** allows the ECU **80** to determine engine phase on a 720° engine cycle as the intake valve **44** only opens once per every two full rotations of the crankshaft **30** on the four stroke engine cycle. During the compression stroke **103**, power stroke **104**, and exhaust stroke **101** the intake pressure sensed by the intake pressure sensor **64** is close to the barometric air pressure **112** of the outside air.

In order to determine proper engine timing for the ECU **80** to inject fuel from the fuel injector **67** or trigger the ignition of the spark plug **65**, the ECU **80** must have a model of the engine characteristics having inputs from the intake air pressure sensor **64** and optionally the crank position sensor **65** to determine crankshaft position **140** while the engine **10** is operating. An example of a model, for example, but without limitation, is the implementation of a predictive model where crankshaft position is based on the time period of the previous cycle **115** of intake air pressure fluctuations **100** to **110** of the intake air pressure signal **120** to predict crankshaft position for the next cycle **125** to **130**. With a model of this type, the

engine timing of each cycle **115** is based on the previous engine cycle. Other control algorithms could be implemented, without limitation, with the same technology of this invention for sensing engine speed N, phase, and/or position.

It is to be noted that the intake air pressure signal **120** may have additional small fluctuations (not shown) depending upon engine **10** operating conditions. These fluctuations may take the form of signal "noise" and can be attenuated via electronic filter within the ECU **80** or digitally by software in the ECU **80** itself to attenuate predetermined frequencies. By including any passive form of signal smoothing, time delays and signal attenuation may be introduced into the present air pressure signal **120** to the ECU **80**.

Of course, the foregoing description is that of certain features, aspects and advantages of the present invention to which various changes and modifications may be made without departing from the spirit or scope of the present invention. While I have shown and described specific embodiments of this invention, further modifications and improvements will occur to those skilled in the art. All such modifications that retain the basic underlying principles disclosed and claimed herein are within the scope of this invention. The present invention, therefore, should only be defined by the appended claims.